DEFECT DETECTION ON ELECTRICAL POWER EQUIPMENT USING THERMAL IMAGING TECHNOLOGY

GEOFFREY ASIEGBU OGADIMMA

A thesis submitted in fulfillment of the requirement for the award of the degree of Master of Engineering in Electrical Engineering

Faculty of Electrical and Electronics Engineering
UNIVERSITI MALAYSIA PAHANG

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LIST OF SYMBOLS

μ_r, μ_g, μ_b	Mean value of red, green, blue colors in the IRT image
r_i, g_i, b_i	Pixel value of red, green, blue colors in the IRT image
N	Total Number of image pixels of the IRT image
$\sigma_r^2, \sigma_g^2, \sigma_b^2$	Variance values red, green, blue color components in the IRT image
$\sigma_{rg}^2, \sigma_{rb}^2, \sigma_{gb}^2$	Covariance values of pixel similarity between color combinations in the IRT image
e	Exponential Function Applied in Gaussian PDF
π	Pi = 3.1429 (constant)
ΔT	Temperature difference between equipment and ambient
Δt	Temperature difference between similar equipment
N_{gv}	Normalized grayscale value
T_i	Optimal threshold value of each extracted regions

LIST OF ABBREVIATIONS

RGB	Red, Green, Blue color model or space
IRT	Infrared Thermal Image
ROC	Receiver Operating Characteristics
TN	True Negative
TP	True Positive
FN	False Negative
FP	False Positive
PPV	Predictive Positive Value
FPR	False Positive Rate
TPR_{value}	Actual pixel value but does not represent real thermal value
TH_{real}	Real equipment thermal value

ABSTRACT

Electrical power equipment and components are vital constituent portions of human existence. They are found virtually in every domestic home and manufacturing industries. These electrical power equipment, operates at a temperature above absolute zero, certainly emit infrared radiation. In some power distribution systems, existing station equipment could no longer withstand the short circuit current capacity causing equipment break down. The electrical equipment failures can be avoided if the temperature threshold is detected in order to take timely corrective action. Quality control and part inspection have done considerably well in the area of manufacturing but not yet gotten to its fully robust thermal imaging technology application. Thermal image is a term comes from the infrared thermography. It has gained its popularity in the last few decades over other predictive maintenance techniques due to its many advantages such as contact-less, easy to interpret the thermal data, large area of inspection as well as free from dangerous radiation. This research project proposed defect detection on electrical power equipment using thermal imaging technology. The aim is to study the thermal characteristic of electrical power equipment, secondly, to design defect detection technique and make a fault decision as well as comparing results with other defect detection techniques and international thermal evaluation standard. A thermal imager is used to acquire thermal images of the tested electrical facilities under various operating conditions. The thermal image in RGB color space is normalized and morphologically dissected using image mean, variance, and covariance which is applied on the mixtures of Gaussian Probability Distribution Function (GPDF) through which threshold values were determined. Using the threshold values similar pixels are connected via maximum likelihood criterion been function of short circuit OR logic operator. The predetermined threshold values are optimized using Receiver Operating Characteristic (ROC) curve and the area under convex hull. Regions of electrical thermogram are segmented using the optimal threshold values. Various features in the infrared thermal (IRT) image are extracted in order to detect anomalies. Classification and decision are made in terms of colors and temperature difference values. Matlab image processing software is used to implement these procedures. Application of this system is quite simple, user friendly, time and cost effective. In conclusion, a total of 111 different electrical power distribution facilities was experimentally inspected. Within the limits of experimental errors, the results of the analysis showed that 99.9% sensitivity and 99.72% accuracy was achieved with an error rate of 0.28 that was attributed to mistakes due to over and less caution during experimental thermal inspection of electrical facilities. The results suggested that, the method provides an accurate identification of defective parts can be extended for further applications. The results also suggest that the system works well enough to help improve the value and efficiency of consumable electrical power equipment reducing the number of faults in the power distribution line, ensuring safety of the workers and users of electricity, protecting electrical power facilities from damage due to over-heating or fire. Above all, testing, inspection and preventive maintenance work become safer, easier, and faster with a reasonably high degree of accuracy with this result-oriented defect detection scrutiny system on electrical power facilities.

ABSTRAK

Peralatan kuasa elektrik dan komponennya merupakan konstituen penting kewujudan manusia. Mereka dijumpai hampir di setiap rumah domestik dan industri pembuatan. Peralatan kuasa elektrik, beroperasi pada suhu di atas sifar mutlak, sudah tentu mengeluarkan sinaran inframerah. Dalam sesetengah sistem pengagihan kuasa, peralatan yang sedia ada tidak dapat lagi menahan kapasiti arus litar pintas yang menyebabkan peralatan rosak. Kerosakan peralatan elektrik boleh dielakkan jika ambang suhu dikesan untuk mengambil tindakan pembetulan yang tepat pada masanya. Penggunaan pengimejan haba di dalam bidang kawalan kualiti dan pemeriksaan komponen dalam bidang pembuatan adalah agak baik tetapi belum mencapai tahap automatik sepenuhnya. Imej haba adalah istilah yang berasal dari termografi inframerah. Ia telah mendapat populariti dalam beberapa dekad yang lalu berbanding teknik-teknik penyelenggaraan ramalan lain kerana banyak kelebihan seperti kurang-sentuhan, mudah untuk mentafsirkan data haba, kawasan pemeriksaan yang besar serta bebas daripada sinaran berbahaya. Projek penyelidikan ini mencadangkan pengesanan kerosakan pada peralatan kuasa elektrik menggunakan teknologi pengimejan haba. Tujuannya adalah untuk mengkaji ciri-ciri haba peralatan kuasa elektrik, dan untuk mereka bentuk teknik pengesana kerosakan serta memberitahu pengguna bahagian yang mengalami kerosakan. Keputusan yang dikeluarkan oleh projek ini akan dibandingkan dengan lain-lain teknik pengesanan kerosakan dan standard penilaian haba antarabangsa. Kamera pengimejan haba digunakan untuk memperolehi imej haba daripada peralatan elektrik digunakan di dalam pelbagai keadaan operasi. Imej haba dalam ruang warna RGB dinormalkan dan dipecahkan secara morfologi menggunakan imej min, varians dan kovarians yang digunakan pada campuran Gaussian Kebarangkalian Pengagihan Fungsi (GPDF) di mana nilai-nilai ambang ditentukan. Piksel yang mempunyai nilai-nilai di dalam lingkungan nilai ambang akan disambungkan melalui kriteria kebolehjadian maksimum bagi fungsi litar pintas ATAU operator logik. Nilai ambang yang telah ditetapkan dioptimumkan menggunakan keluk "Receiver Operating Characteristic (ROC)" dan kawasan di bawah cembung badan. Pelbagai ciri dalam imej haba inframerah (IRT) imej yang diambil diekstrak untuk mengesan anomali. Klasifikasi dan keputusan dibuat dari segi warna dan nilai perbezaan suhu. Fungsi pemprosesan imej di dalam Matlab digunakan untuk melaksanakan prosedur ini. Penggunaan sistem ini adalah agak mudah, mesra pengguna, masa dan kos efektif. Ujian dijalankan ke atas sebanyak 111 peralatan elektrik yang berbeza. Dalam had kesilapan eksperimen, keputusan analisis menunjukkan bahawa 99.9% kepekaan dan ketepatan 99.72% telah dicapai dengan kadar kesilapan 0.28 yang telah dikaitkan dengan kesilapan kerana kurang atau terlalu berhati-hati semasa pemeriksaan terma eksperimen kemudahan elektrik. Keputusan menunjukkan bahawa, kaedah menyediakan pengenalan tepat bahagian yang rosak boleh dilanjutkan bagi permohonan yang selanjutnya. Keputusan juga menunjukkan bahawa sistem kerja-kerja yang cukup baik untuk membantu meningkatkan nilai dan kecekapan guna peralatan kuasa elektrik mengurangkan jumlah kerosakan dalam talian pengagihan kuasa, memastikan keselamatan pekerja dan pengguna elektrik, melindungi kemudahan kuasa elektrik daripada kerosakan yang disebabkan oleh kepada lebih-pemanasan atau api. Paling penting, ujian, pemeriksaan dan kerja-kerja penyelenggaraan pencegahan menjadi lebih selamat, lebih mudah, dan lebih cepat dengan tahap yang cukup tinggi ketepatan dengan ini kecacatan berorientasikan hasil pengesanan sistem penelitian mengenai kemudahan elektrik.

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APPENDIX D

LIST OF PUBLICATIONS

Geoffrey O. Asiegbu, Ahmed M. A. Haidar, Kamarul Hawari, "Thermal Defect Analysis on Transformer Using a RLC Network and Thermography," Circuit and Systems, 2013, 4, 52-60 doi:10.4236/cs.2013.41058.

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